STANDARDIZED CATCH RATES OF JUVENILE GOLIATH GROUPER, *EPINEPHELUS ITAJARA*, FROM THE EVERGLADES NATIONAL PARK CREEL SURVEY, 1973-1999

by

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ABSTRACT

Juvenile goliath grouper (*Epinephelus itajara;* Lichtenstein, 1822) are generally found in shallow mangrove habitat. Their historical center of abundance is the Ten Thousand Islands area of southwest Florida. Detailed catch and effort data are available from this region from 1973-1999. The data were collected by Everglades National Park (ENP) during voluntary dockside interviews of sport fishermen. Interviewers record landings and releases. Using this data, a standardized index of abundance was created for juvenile goliath grouper. The delta-lognormal index was constructed by combining two general linear models, a binomial model fit to the proportion of positive trips, and a lognormal model fit to catch rates. As expected, the index shows a substantial decline in abundance during the late 1970s and early 1980s. Since that time, recovery is evident. Relative abundance is very high in 1995 and 1996, suggesting that strong year classes have recently occurred in ENP. These results support recent anecdotal reports of increasing populations of goliath grouper in U.S. waters.

INTRODUCTION

Goliath grouper occur in tropical areas of the western Atlantic Ocean, from Florida south to Brazil, including the Gulf of Mexico and the Caribbean Sea (Heemstra and Randall, 1993). They are the largest of the western north Atlantic groupers, reaching a size of 2.0 to 2.5 m TL (Heemstra and Randall 1993) and 320 kg (Smith, 1971). Adults are typically found in shallow, inshore waters at depths less than 40 m (Sadovy and Eklund, 1999). They generally occupy limited home ranges near areas of refuge such as caves, shipwrecks, and rocky ledges (Nagelkerken, 1981). Goliath grouper are slow to mature and long-lived. According to Bullock et al. (1992) females reach sexual maturity at 1.2 to 1.35 m TL and 6-7 years of age while males are often mature at 1.15 m TL and 5-6 years of age. The maximum recorded age from an exploited population of goliath grouper is 37 years (Bullock et al., 1992).

Goliath grouper may be unusually susceptible to overfishing due to their unwary behavior, conspicuous size, apparent site specificity and relatively long life span. Inshore populations began to decline in the 1950s, likely due to fishing on spawning aggregations and spearfishing of adults (Sadovy and Eklund, 1999). During the late 1970s and 1980s, fishing effort on goliath increased rapidly, while subsequent catches decreased. By 1989, substantial reductions in the number and size of spawning aggregations were noted (DeMaria[1]; Sadovy and Eklund, 1999). These observations led to strict regulatory measures. In 1990, the Gulf of Mexico Fisheries Management Council (GMFMC) prohibited the landing of goliath grouper in Gulf of Mexico federal waters (GMFMC, 1990). Identical moratoria were enacted in 1990 by the South Atlantic Fisheries Management Council (SAFMC) and the State of Florida. In 1993, the Caribbean Fisheries Management Council (CFMC) and the territorial government of the U.S. Virgin Islands expanded the moratorium to federal and territorial waters of the U.S. Caribbean.

Recent anecdotal reports from U.S. fishers and divers suggest that goliath grouper populations are increasing in U.S. waters. Due, in part, to these reports, in 2003, the GMFMC requested an assessment of goliath grouper to develop estimates of current status and recovery time. The assessment was completed at the NOAA Fisheries Southeast Fisheries Science Center, Miami Laboratory, and is described by Porch et al. (2003). This effort required the development of at least one index of abundance. This document summarizes the creation of one such index, a standardized index of abundance for juvenile goliath grouper. Additional indices developed for the 2003 assessment of goliath grouper are reported in Porch and Eklund (2003).

The current center of abundance for Gulf populations of goliath grouper is the Ten Thousand Islands area of southwestern Florida (Sadovy and Eklund, 1999). Here, extensive estuarine, and swamp mangrove habitats exist, ideal for juvenile goliath grouper (Bullock and Smith, 1991). The Ten Thousand Islands area is located near Chokoloskee and Everglades City, Florida, and is predominantly contained within the borders of Everglades National Park (ENP; Fig. 1). Thus, fisheries data provided by the park may be useful for the development of a standardized abundance index of juvenile goliath grouper.

ENP was established in 1947, and is located in southern Florida. Systematic collection of fisheries data commenced within the park in 1958 (Davis and Thue, 1979). The evolution of the monitoring procedures are detailed by Davis and Thue (1979) and Schmidt et al. (2002). During the first ten years (1958-1969) the program was conducted by the University of Miami's Institute of Marine Science, and evaluated only the sport fishery. Estimates of catch and catch per unit effort (CPUE) were recorded only for specific species (not including goliath grouper) landed by sport fishermen operating out of Flamingo. In 1972, the National Park Service expanded the monitoring program to include daily trip ticket reports from commercial permit holders, and park-wide monitoring of sport fishing and commercial catch and effort. At this time, the species list was expanded to include all species typically landed within ENP. Fish length measurements were collected as of 1974 and, in 1980, routine monitoring of the Chokoloskee-Everglades City boat ramps began.

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MATERIAL AND METHODS

Data Collection

ENP data were provided by the National Park Service, South Florida Ecosystem Office[2]. Detailed descriptions of ENP data collection and recording formats include Higman (1967), Davis and Thue (1979) and Tilmant et al. (1986). To summarize, sport fishermen are interviewed by ENP personnel at the Flamingo and Chokoloskee-Everglades City boat ramps upon completion of their trip. Data routinely recorded includes trip origin, area fished (Fig. 1), number of fish kept and released by species, number of anglers, hours fished, species preference, angler residence, type of fisherman (skilled, family, novice, sustenance). When possible, fish length measurements are also recorded.

Since 1990, landings of goliath grouper have been prohibited in all U.S. Federal and State of Florida waters. However, goliath grouper continue to be captured and released by sport fishermen in ENP. Therefore, ENP records, which include fish kept and released, can be used to develop a standardized abundance index. For each trip, we calculated catch per unit effort using Eq. 1.

$$(1) \qquad CPUE = \frac{Goliath\,Kept + Goliath\,\mathrm{Re}\,leased}{Anglers * Hours\ Fished}$$

Defining Species Associated with Goliath Grouper

The ENP dataset contains useful information from 165,734 sport fishing trips that took place during 1973-1999. Trips were excluded if essential fields were missing or unfeasible. Commonly landed species include spotted seatrout (*Cynoscion nebulosus*), crevalle jack (*Caranx hippos*) gray snapper (*Lutjanus griseus*) and red drum (*Sciaenops ocellatus*). These species were observed on 44%, 38%, 33% and 28% of the trips, respectively. In contrast, goliath grouper were captured on only 1.8% of the trips. Due to variations in fishing location, depth, bait and gear choice, we believe that many fishing trips that targeted these common species had low probability to capture a goliath grouper. In the absence of detailed and reliable data regarding fishing location, bait choice, etc., we used an association statistic to attempt to identify trips with a higher probability of catching goliath grouper. The association statistic (Eq. 2) was developed

$$(2) \qquad Association\ Statistic = \frac{Trips\ with\ Goliath + Species\ X}{Trips\ with\ Goliath} \Bigg/ \frac{Trips\ with\ Species\ X}{Total\ Trips}$$

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using the species composition of the catch, as proposed by Heinemann[3], and previously described by Cass-Calay and Bahnick (2002). Species preference was rejected as a method to restrict the data for two reasons. First, very few fishermen report targeting goliath grouper since the 1990 moratorium. Second, there is concern that fishermen are less likely to report targeting a species if they failed to land that species.

We calculated the association statistic for all species reported by 100 or more sport fishing trips during 1973-1999. We assumed that a species was associated with goliath grouper if the association statistic was =2.0. If a trip kept or released a goliath grouper, or a species identified as an associate, that trip was included in the dataset used to estimate standardized CPUE.

Index Development

In order to develop a well balanced sample design, it was necessary to construct the following categorical variables. The factor PARTY refers to the skill level of the fishing party. Two levels were considered.

"Skilled" = Fishers identified as "skilled" by ENP.
"Other" = Fishers identified as "family", "novice" or "sustenance" by ENP.

The factor SEASON was constructed from MONTH to create three periods generally reflective of water temperatures and rainfall in the shallow waters of ENP. Those periods were:

MONTH = (Nov, Dec, Jan, Feb) then SEASON = 1
MONTH = (Mar, Apr, May, Jun) then SEASON = 2
MONTH = (Jul, Aug, Sept, Oct) then SEASON = 3

The factor TARGET was defined using the reported species preference. If the species preference listed was goliath grouper, TARGET = "Goliath". If not, TARGET = "Other".

The factor AREA was constructed using the ENP definitions (Fig. 1) with one exception, areas 1 and 2 were combined in order to obtain sufficient observations of goliath grouper. Although the areas were constructed by ENP to delimit different habitats, we felt areas 1 and 2 were sufficiently alike to permit combination.

We used the delta lognormal model approach (Lo et al. 1992) to develop the standardized index of abundance. This method combines separate generalized linear modeling (GLM) analyses of the proportion of successful trips (trips that kept or released a goliath grouper) and the positive catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA).

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Factors considered as possible influences on the proportion of successful trips included YEAR, SEASON, AREA, PARTY and TARGET. During this GLM procedure, we fit a type-3 model, assumed a binomial error distribution, and selected the logit link. The response variable was proportion positive trips. We examined the same factors during the analysis of catch rates on positive trips. In this case, a type3 model assuming lognormal error distribution was employed. The linking function selected was "normal", and the response variable was ln(CPUE).

For each GLM, we used a stepwise approach to quantify the relative importance of the factors. First the null model was run. These results reflect the distribution of the nominal data. Next we added each potential factor to the null model one at a time, and examined the resulting reduction in deviance per degree of freedom. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was =1%. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects except interaction terms containing YEAR (e.g. YEAR*AREA). These were modeled as random effects. To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value of the series.

RESULTS AND DISCUSSION

ENP records include length measurements for 420 goliath grouper landed within the park from 1974-2001 (Fig. 2). The mean total length reported is 605 mm (SD±192 mm). Unexpectedly, a secondary mode occurs at 950-1000 mm because ENP technicians record length only to 999 mm. Therefore, all goliath grouper larger than 1 m are included in this length bin (26 of 420 observations). However, as goliath grouper do not mature until they are in excess of 1 m (Bullock et al., 1992), it is apparent that the majority of individuals captured within ENP are juveniles.

Species classified as associates of goliath grouper, and their relevant association statistics are summarized in Table 1. It is important to emphasize that the defined assemblage does not require, or suggest strict biological association. An association statistic equal to 1.0 implies that a given species is captured as frequently in association with goliath grouper as random chance would predict. Values >1.0 indicate that a given species is found more often in association with goliath grouper than expected. The maximum value of the association statistic depends on the rarity of the "target" species. Of the 165,734 interviewed trips, 14,026 landed goliath grouper, or a species with an association statistic =2.0. Only these trips were included in the data set used to develop the standardized index of abundance.

The stepwise construction of the binomial model of the probability of catching goliath grouper is summarized in Table 2. The final model was ***PROPORTION POSITIVE TRIPS =***

TARGET + YEAR. Annual variations in the proportion of positive trips are shown in Figure 3. From 1973-1981, approximately 26% of the sport fishing trips included in the analysis reported the capture of one or more goliath grouper. This percentage declined to ~12% from 1982-1992. During the most recent years, 1993-1999, substantial recovery is noted. During this period, ~26% of trips included in the analysis captured goliath. Diagnostic plots were examined to evaluate the fit of the binomial model. The distribution of the chi-square residuals (Fig. 4) indicates an acceptable fit, although some outliers were noted. These occurred in strata containing few observations, and were not unexpected. The frequency distribution of the proportion of positive trips, by year and target was also acceptable (Fig. 5).

The stepwise construction of the lognormal model of catch rates on positive trips is summarized in Table 3. The final model was ***ln(CPUE) = YEAR + PARTY + AREA + YEAR*AREA.*** Annual values of nominal CPUE on positive trips are shown in Figure 6. CPUE was lowest during the 1980s and early 1990s. A rapid increase in nominal CPUE occurs after 1993 with the highest catch rates on record occurring during 1995 and 1996. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 7), although the range was narrower during the middle of the time series. This is due, in part, to substantially fewer "positive" trips during those years. Also as expected, the frequency distribution of ln(CPUE), by year, party and area, approximated a normal distribution (Fig. 8). In summary, all diagnostic plots met our expectations, and supported an acceptable fit to the selected models.

The delta-lognormal abundance index, with 95% confidence intervals, is shown in Figure 9. To allow quick visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 4. No index estimate was possible for the year 1974 because only one positive trip was reported. The standardized abundance index is quite similar to the nominal CPUE series. These results suggest that within ENP, captures of juvenile goliath grouper have increased substantially since 1992, and that one or more large year classes were present during 1995 and 1996.

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Table 1. Results of the calculations used to identify species associated with goliath grouper. Species were assumed to be associated with goliath grouper if the association statistic was ≥ 2.0. Shaded rows indicate associated species.

Species X Common Name	Species X Scientific name	ENP Species Code	Trips with Goliath and Species X	Trips with Species X	Assoc. Stat.
Goliath grouper	*Epinephelus itajara*	8815	2988	2988	55.47
Schoolmaster	*Lutjanus apodus*	5804	15	110	7.56
Nurse shark	*Ginglymostoma cirratum*	6901	106	976	6.02
Misc Sawfishes	Pristidae	8000-8002	7	69	5.63
Bull Shark	*Carcharhinus leucas*	1905	14	141	5.51
Gag	*Mycteroperca microlepis*	8837	270	2846	5.26
Misc. Serranids	Serranidae	8800	246	3799	3.59
Cobia	*Rachycentron canadum*	8101	53	864	3.40
Black grouper	*Mycteroperca bonaci*	8835	34	555	3.40
Toadfish	Batrachoididae	1200	12	205	3.25
Misc Mullets	Mugilidae	6100	26	478	3.02
Mutton snapper	*Lutjanus analis*	5803	7	139	2.79
Lane snapper	*Lutjanus synagris*	5811	30	619	2.69
Permit	*Trachinotus falcatus*	1823	19	500	2.11
Tripletail	*Lobotes surinamensis*	5601	45	1250	2.00
Atlantic spadefish	*Chaetodipterus faber*	4101	2	57	1.95
Gray snapper	*Lutjanus griseus*	5808	1732	53999	1.78
Blacktip Shark	*Carcharhinus limbatus*	1906	113	3634	1.72
Greater amberjack	*Seriola dumerili*	1818	2	65	1.71
Unid. Cichlid spp.	Cichlidae	2413	9	296	1.69
Red Grouper	*Epinephelus morio*	8816	12	401	1.66
Snook	*Centropomus undecimalis*	2204	794	26953	1.63
Lookdown	*Selene vomer*	1817	3	102	1.63
Misc. Stingrays	Dasyatididae	3500	53	1849	1.59
Spanish mackerel	*Scomberomorus maculatus*	8611	123	4316	1.58
Tarpon	*Megalops atlanticus*	3902	118	4431	1.48
Misc. Sea catfish	Ariidae	800	223	8908	1.39
Oscar	*Astronotus ocellatus*	2402	4	165	1.34
Lemon shark	*Negaprion brevirostris*	1917	7	291	1.33
Bluestriped grunt	*Haemulon sciurus*	7714	15	628	1.32
Misc. Snappers	Lutjanidae	5800	23	1007	1.27
Misc. L/E Flounders	Bothidae	1500	49	2156	1.26
Misc. Jacks and Pompanos	Carangidae	1800	12	537	1.24
Gafftopsail catfish	*Bagre marinus*	802	422	18948	1.24
Sheepshead	*Archosargus probatocephalus*	9001	528	23734	1.23
Black drum	*Pogonias cromis*	8521	266	12016	1.23
Bluefish	*Pomatomus saltatrix*	7801	19	869	1.21
Stone crab	*Minippe mercenaria*	2740	2	94	1.18
Red drum	*Sciaenops ocellatus*	8522	962	46478	1.15

Table 1. (continued)					
Misc. Porgies	Sparidae	9000	3	146	1.14
Blue runner	*Caranx crysos*	1803	30	1474	1.13
Southern flounder	*Paralichthys lethostigma*	1522	5	254	1.09
Misc Gars	Lepisosteidae	5500	2	102	1.09
Pufferfish	Tetradontidae	9600	113	6032	1.04
Crevalle jack	*Caranx hippos*	1804	1134	62923	1.00
Pinfish	*Lagodon rhomboides*	9012	45	2522	0.99
Sea catfish	*Arius felis*	801	793	45349	0.97
Great hammerhead	*Sphyrna mokarran*	9202	7	406	0.96
Great barracuda	*Sphyraena barracuda*	9101	29	1706	0.94
Misc Grunts	Haemulidae	7700	64	3934	0.90
Misc. remoras	Echeneidae	3700	3	191	0.87
Ladyfish	*Elops saurus*	3901	614	39494	0.86
Spiny lobster	*Panulirus argus*	1211	1	65	0.85
Lizardfishes	Synodontidae	9500	26	1693	0.85
Southern puffer	*Sphoeroides nephelus*	9606	4	262	0.85
Misc. Requiem Sharks	Carcharhinidae	1900	83	5578	0.83
Florida pompano	*Trachinotus carolinus*	1822	19	1349	0.78
Spotted Seatrout	*Cynoscion nebulosus*	8506	1030	73709	0.78
Yellowtail snapper	*Ocyurus chrysurus*	5813	3	215	0.77
Bonnethead	*Sphyrna tiburo*	9203	53	3923	0.75
Cichlids	Cichlidae	2400	1	83	0.67
Grass porgy	*Calamus arctifrons*	9003	1	86	0.64
Blue crab	*Callinectes sapidus*	2532	33	3278	0.56
Leatherjacket	*Oligoplites saurus*	1815	1	106	0.52
Cero	*Scomberomorus regalis*	8612	1	108	0.51
White mullet	*Mugil curema*	6103	2	221	0.50
Misc. Needlefish	Belonidae	1300	3	339	0.49
Inshore lizardfish	*Synodus foetens*	9504	2	263	0.42
Sand seatrout	*Cynoscion arenarius*	8505	7	946	0.41
Sailors choice	*Haemulon parra*	7712	1	143	0.39
Silver perch	*Bairdiella chrysura*	8503	1	156	0.36
Largemouth bass	*Micropterus salmoides*	2126	7	1389	0.28
Gulf kingfish	*Menticirrhus littoralis*	8517	2	462	0.24
Sand perch	*Diplectrum formosum*	8810	3	912	0.18
Striped mullet	*Mugil cephalus*	6102	1	466	0.12
Pigfish	*Orthopristis chrysoptera*	7716	0	129	0.00
Yellow jack	*Caranx bartholomaei*	1802	0	85	0.00
Florida gar	*Lepisosteus platyrhincus*	5504	0	79	0.00
Bonefish	Abulidae	200/201	0	61	0.00
Misc. Hammerhead sharks	Sphyrnidae	9200, 9204, 9201	0	61	0.00

Table 2. A summary of formulation of the binomial model. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF = 1.0% (bold blue font). The final model was SUCCESS = TARGET + YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13556	14287.7	1.0540		-7143.9		
SEASON	13554	14191.8	1.0471	0.66	-7095.9	95.95	0.00000
PARTY	13555	14170.7	1.0454	0.81	-7085.3	117.06	0.00000
AREA	13552	14151.5	1.0442	0.92	-7075.8	136.22	0.00000
YEAR	13531	13777.3	1.0182	3.39	-6888.6	510.45	0.00000
TARGET	13555	13473.4	0.9940	5.69	-6736.7	814.34	0.00000

The explanatory factors in the base model are: TARGET

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13555	13473.4	0.9940		-6736.7		
SEASON	13553	13417.1	0.9900	0.40	-6708.6	56.28	0.00000
PARTY	13554	13379.4	0.9871	0.69	-6689.7	93.99	0.00000
AREA	13551	13366.6	0.9864	0.76	-6683.3	106.80	0.00000
YEAR	13530	12885.0	0.9523	4.19	-6442.5	588.38	0.00000

The explanatory factors in the base model are: TARGET YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13530	12885.0	0.9523		-6442.5		
SEASON	13528	12845.6	0.9496	0.29	-6422.8	39.39	0.00000
PARTY	13529	12834.4	0.9487	0.39	-6417.2	50.65	0.00000
AREA	13526	12803.9	0.9466	0.60	-6401.9	81.13	0.00000

The explanatory factors in the base model are: TARGET YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	13530	12885.0	0.9523		-6442.5		
YEAR*TARGET	13509	12837.5	0.9503	0.21	-6418.7		

Table 3. A summary of formulation of the lognormal model. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF = 1.0% (bold blue font). The final model was log(CPUE) = YEAR + PARTY + AREA +YEAR*AREA.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2982	1641.8	0.5506		-3342.0	.	.
TARGET	2981	1641.6	0.5507	-0.02	-3341.9		
SEASON	2980	1633.1	0.5480	0.49	-3334.1	15.78	0.00037
PARTY	2981	1606.2	0.5388	2.16	-3309.4	65.32	0.00000
AREA	2978	1593.9	0.5352	2.81	-3297.9	88.31	0.00000
YEAR	2957	1569.2	0.5307	3.63	-3274.6	134.78	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2957	1569.2	0.5307		-3274.6		
TARGET	2956	1563.1	0.5288	0.35	-3268.8	11.59	0.00066
SEASON	2955	1561.0	0.5283	0.46	-3266.8	15.70	0.00039
AREA	2953	1543.2	0.5226	1.53	-3249.7	49.97	0.00000
PARTY	2956	1544.6	0.5225	1.54	-3251.0	47.19	0.00000

The explanatory factors in the base model are: YEAR PARTY

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2956	1544.6	0.5225		-3251.0		
TARGET	2955	1541.4	0.5216	0.17	-3248.0	6.11	0.01348
SEASON	2954	1538.1	0.5207	0.36	-3244.7	12.67	0.00177
AREA	2952	1518.6	0.5144	1.55	-3225.7	50.68	0.00000

The explanatory factors in the base model are: YEAR PARTY AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2952	1518.6	0.5144		-3225.7		
SEASON	2950	1514.0	0.5132	0.24	-3221.2	9.04	0.01089
TARGET	2951	1514.5	0.5132	0.24	-3221.6	8.11	0.00441

The explanatory factors in the base model are: YEAR PARTY AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2952	1518.6	0.5144		-3225.7		
AREA*PARTY	2948	1509.1	0.5119	0.49	-3216.4	18.69	0.00090
YEAR*PARTY	2833	1443.4	0.5095	0.95	-3150.0		
YEAR*AREA	2858	1453.6	0.5086	1.13	-3160.5	130.48	0.00765

The explanatory factors in the base model are: YEAR PARTY AREA YEAR*AREA

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	2858	1453.6	0.5086		-3160.5		
YEAR*PARTY	2833	1443.4	0.5095	-0.17	-3150.0		
AREA*PARTY	2854	1449.1	0.5077	0.17	-3155.8	9.30	0.05398

Table 4. The relative nominal CPUE, proportion positive trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for juvenile goliath grouper captured in Everglades National Park, 1973-1999.

YEAR	Relative Nominal CPUE	Positive Trips	Proportion Positive Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (index)
1973	1.049	109	0.311429	1.112	0.852	1.451	0.134
1974	N/A	1	0.002	N/A	N/A	N/A	N/A
1975	0.757	106	0.187611	0.937	0.700	1.254	0.147
1976	1.354	189	0.319797	1.386	1.112	1.726	0.110
1977	1.306	186	0.309484	1.184	0.950	1.474	0.110
1978	1.349	150	0.268817	1.276	0.993	1.640	0.126
1979	1.000	66	0.226804	0.966	0.677	1.379	0.179
1980	1.341	117	0.259424	1.107	0.847	1.447	0.134
1981	0.994	93	0.216783	0.816	0.599	1.111	0.155
1982	0.698	53	0.119639	0.623	0.409	0.948	0.212
1983	0.609	66	0.142857	0.719	0.500	1.033	0.183
1984	0.646	60	0.149626	0.785	0.532	1.157	0.196
1985	0.478	35	0.104478	0.542	0.322	0.913	0.265
1986	0.434	38	0.101333	0.525	0.315	0.874	0.259
1987	0.349	30	0.089552	0.437	0.249	0.766	0.287
1988	0.420	31	0.113139	0.578	0.346	0.966	0.261
1989	0.597	73	0.182957	0.705	0.494	1.005	0.179
1990	0.481	60	0.117188	0.675	0.467	0.973	0.185
1991	0.507	50	0.121655	0.795	0.536	1.180	0.199
1992	0.525	65	0.134298	0.819	0.583	1.152	0.172
1993	0.676	99	0.162562	0.879	0.661	1.170	0.144
1994	1.341	240	0.269663	1.354	1.118	1.641	0.096
1995	2.259	210	0.320611	1.897	1.572	2.289	0.094
1996	2.489	329	0.339876	1.875	1.579	2.226	0.086
1997	1.604	246	0.265946	1.513	1.248	1.835	0.096
1998	1.304	146	0.223926	1.232	0.979	1.551	0.116
1999	1.433	136	0.230118	1.263	0.999	1.597	0.118

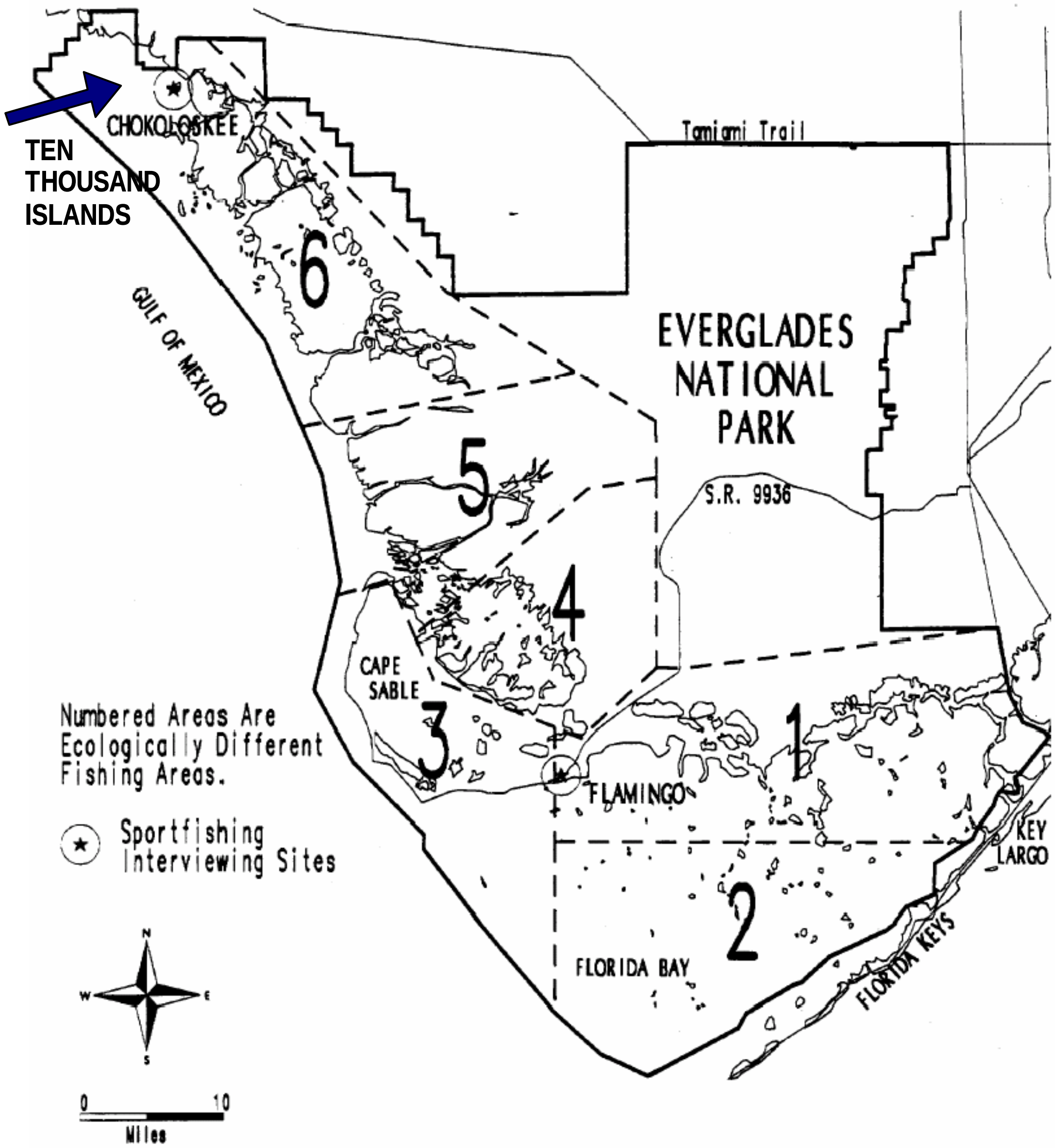

Figure 1. A map of Everglades National Park depicting the defined fishing areas. The Ten Thousand Islands area is located to the northwest, within Area 6. (Reprinted from Schmidt et al. 2002).

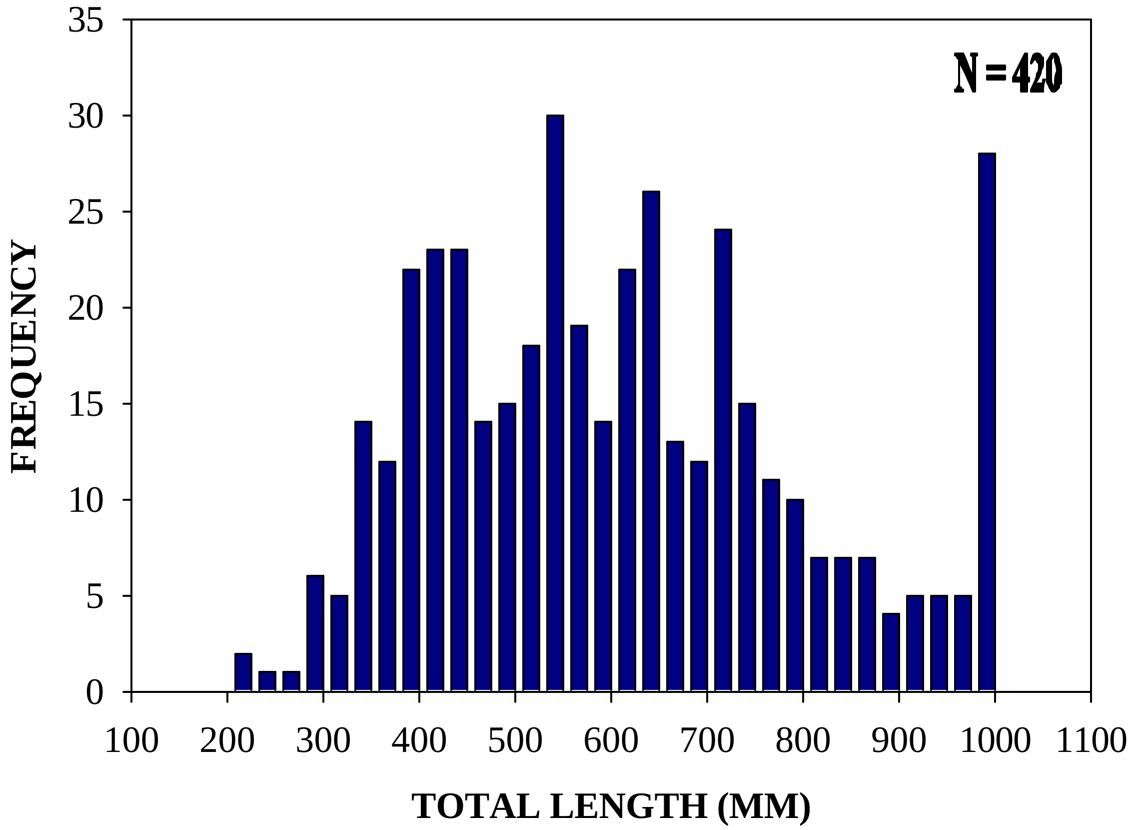

Figure 2. The length frequency distribution of goliath grouper captured in ENP from 1974-2001.

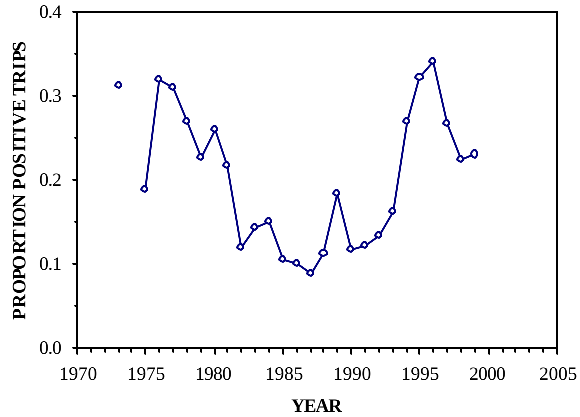

Figure 3. The proportion of positive trips (trips that kept or released a goliath grouper), by year.

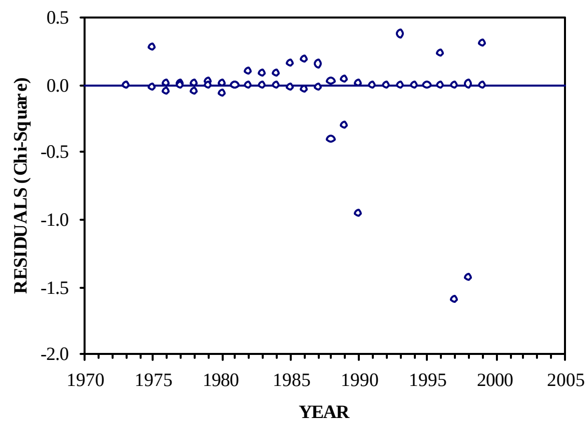

Figure 4. Chi-square residuals for binomial model on proportion positive trips, by year and target.

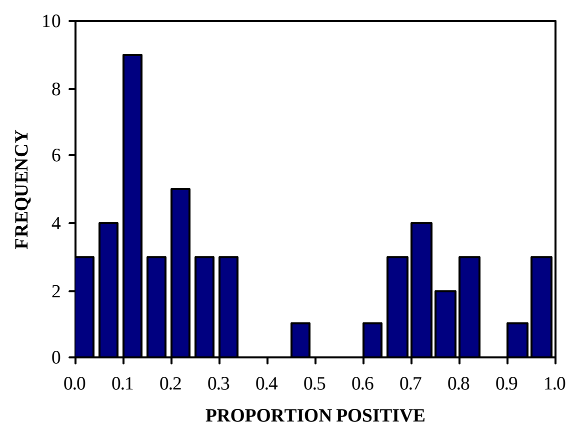

Figure 5. Frequency distribution of proportion positive trips by year and target.

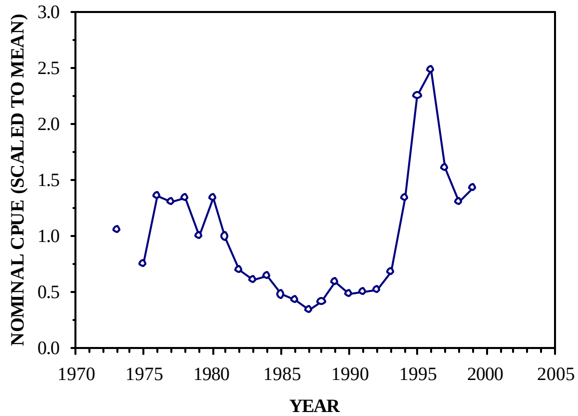

Figure 6. Annual variations in nominal CPUE on positive trips.

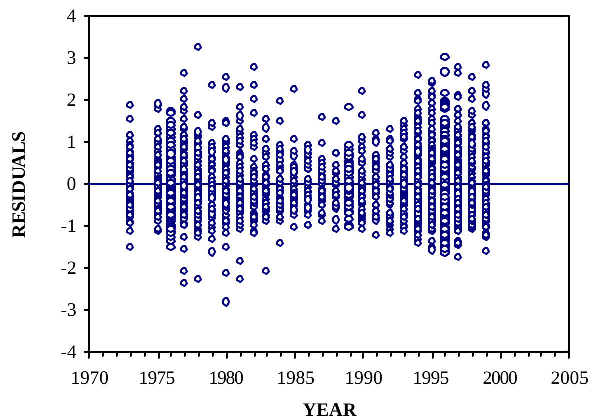

Figure 7. Residuals for the lognormal model on positive catch rates.

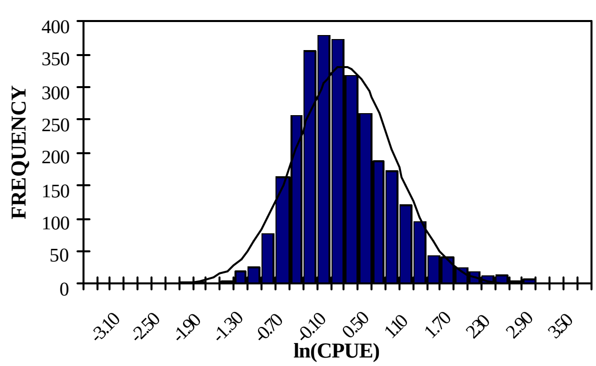

Figure 8. Frequency distribution of ln(CPUE) by year, party and area. The solid line is the expected normal distribution.

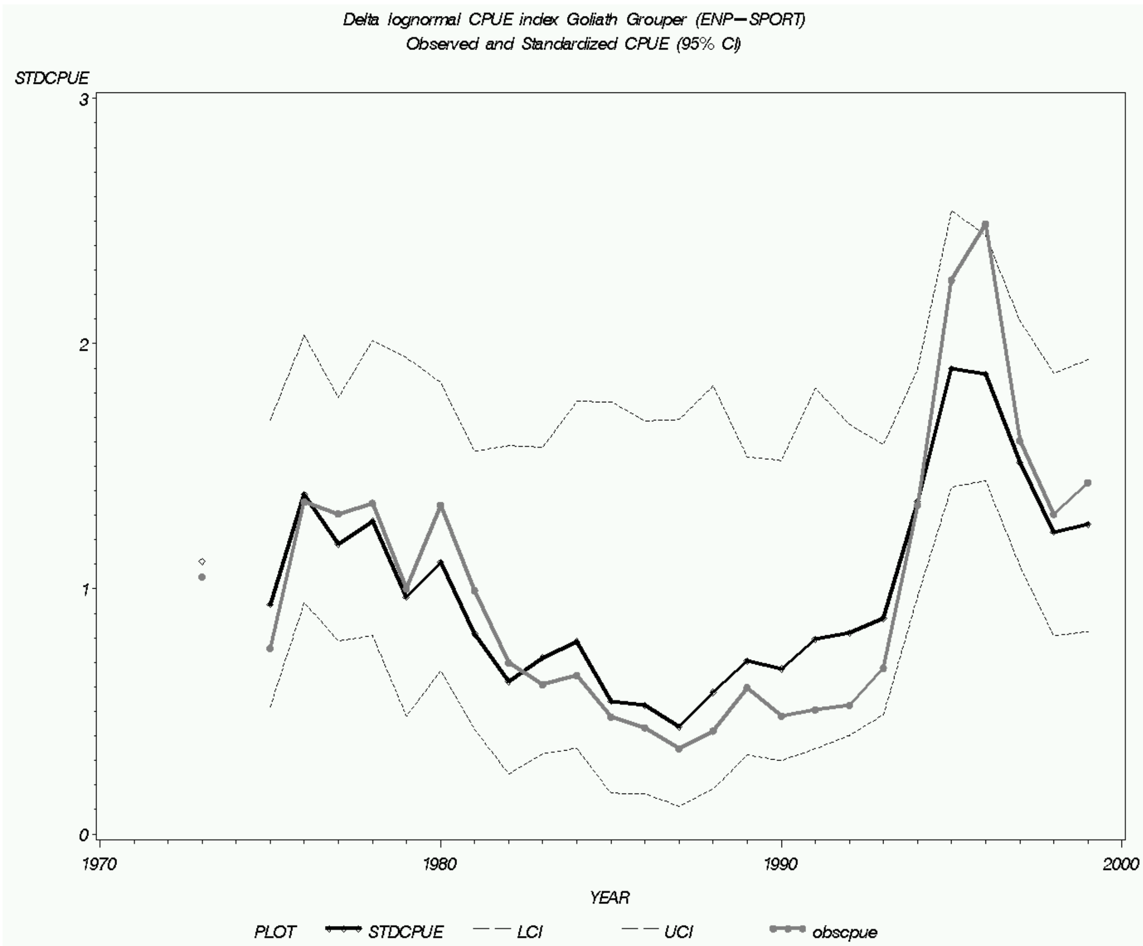

Figure 9. Nominal CPUE (solid gray), standardized CPUE (solid black) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted).